APPLICATION

FOR

UNITED STATES LETTERS PATENT

PATENT APPLICATION

SPECIFICATION

TO ALL WHOM IT MAY CONCERN:

Be it known that Parviz Tayebati of 2 Commonwealth Avenue, 15A, Boston, Massachusetts 02116 has invented certain improvements in WAVELENGTH STABILIZATION OF TUNABLE LASERS BY CURRENT MODULATION of which the following description is a specification.

MB/CORE61.CVR

WAVELENGTH STABILIZATION OF TUNABLE LASERS BY CURRENT MODULATION

Reference To Pending Prior Patent Application

This patent application claims benefit of pending prior U.S. Provisional Patent Application Serial No. 60/161,499, filed 10/26/99 by Parviz Tayebati for WAVELENGTH STABILIZATION OF TUNABLE LASERS BY CURRENT MODULATION (Attorney's Docket No. CORE-61 PROV), which patent application is hereby incorporated herein by reference.

Field Of The Invention

This invention relates to photonic devices in general, and more particularly to tunable lasers.

Background Of The Invention

In pending prior U.S. Patent Application Serial No. 09/105,399, filed 06/26/98 by Parviz Tayebati et al. for MICROELECTROMECHANICALLY TUNABLE, CONFOCAL, VERTICAL CAVITY SURFACE EMITTING LASER AND FABRY-PEROT

FILTER (Attorney's Docket No. CORE-33), and in pending prior U.S. Patent Application Serial No. 09/543,318, filed 04/05/00 by Peidong Wang et al. for SINGLE MODE OPERATION OF MICROMECHANICALLY TUNABLE, HALF-SYMMETRIC, VERTICAL CAVITY SURFACE EMITTING LASERS (Attorney's Docket No. CORE-53), which patent applications are hereby incorporated herein by reference, there are disclosed tunable Fabry-Perot filters and tunable vertical cavity surface emitting lasers (VCSEL's).

More particularly, and looking now at Fig. 1, there is shown a tunable Fabry-Perot filter 5 formed in accordance with the aforementioned U.S. Patent Applications Serial Nos. 09/105,399 and 09/543,318. Filter 5 generally comprises a substrate 10, a bottom mirror 20 mounted to the top of substrate 10, a bottom electrode 15 mounted to the top of bottom mirror 20, a thin support 25 atop bottom electrode 15, a top electrode 30 fixed to the underside of thin support 25, a reinforcer 35 fixed to the outside perimeter of thin support 25, and a confocal top mirror 40 set atop

thin support 25, with an air cavity 45 being formed between bottom mirror 20 and top mirror 40.

As a result of this construction, a Fabry-Perot filter is effectively created between top mirror 40 and bottom mirror 20. Furthermore, by applying an appropriate voltage across top electrode 30 and bottom electrode 15, the position of top mirror 40 can be changed relative to bottom mirror 20, whereby to change the length of the Fabry-Perot cavity, and hence tune Fabry-Perot filter 5.

Correspondingly, and looking next at Fig. 2, a tunable vertical cavity surface emitting laser (VCSEL) 50 can be constructed by positioning a gain medium 55 between bottom mirror 20 and bottom electrode 15. As a result, when gain medium 55 is appropriately stimulated, e.g., by optical pumping or by electrical pumping, lasing can be established between top mirror 40 and bottom mirror 20. Furthermore, by applying an appropriate voltage across top electrode 30 and bottom electrode 15, the position of top mirror 40 can be changed relative to bottom mirror 20, whereby to

change the length of the laser's resonant cavity, and hence tune laser 50.

The present invention is directed to tunable lasers of the type disclosed in the aforementioned U.S. Patent Applications Serial Nos. 09/105,399 and 09/543,318.

Tunable lasers of the type disclosed in the aforementioned U.S. Patent Applications Serial Nos. 09/105,399 and 09/543,318 are highly advantageous since they can be quickly and easily tuned by simply changing the voltage applied across the top electrode and the bottom electrode.

However, it has been found that tunable lasers of the type disclosed in the aforementioned U.S. Patent Applications Serial Nos. 09/105,399 and 09/543,318 can suffer from vibrational problems.

The aforementioned vibrational problems may be due to a variety of factors, such as thermal noise; or noise in the tuning voltage of the laser; or, in the case of an electrically pumped laser, shot noise in the injection current; etc.

Regardless of the cause, the effect of these vibrational problems is to cause the laser to move out of tune. In other words, these vibrational effects cause the output frequency of the laser to change even though the tuning voltage of the laser is held constant. While the extent of this vibration-related frequency shift may be relatively modest (e.g., a 300 MHz shift in the lasing frequency from a 100 MHz vibration frequency), this frequency shift may nonetheless create significant problems in certain types of systems, e.g., WDM communication systems.

See, for example, Fig. 3, which schematically illustrates how the aforementioned vibrational problems may cause a relatively periodic modulation of the lasing frequency; and Fig. 4, which schematically illustrates how the aforementioned vibrational problems may cause a relatively irregular modulation of the lasing frequency.

As a result, an object of the present invention is to provide a method and apparatus for stabilizing

the wavelength of tunable lasers affected by the aforementioned vibrational problems.

Summary Of The Invention

The present invention provides a fast and easy way to compensate for the aforementioned vibrational problems in tunable lasers, by correspondingly adjusting the electrooptical performance of the laser's gain medium, whereby to eliminate the frequency shift due to vibrational factors.

The electrooptical performance of the laser's gain medium is adjusted, in the case of an electrically pumped laser, by changing the injection current used to pump the laser; and the electrical performance of the laser's gain medium is adjusted, in the case of an optically pumped laser, by changing the intensity of the pump laser used to energize the laser.

The system is implemented with a feedback mechanism. A wavelength measuring module detects the difference between the instantaneous wavelength of the

laser and the desired wavelength of the laser, and generates a voltage signal which is representative of this difference. This voltage signal is then used to appropriately modify the electrooptical performance of the laser's gain medium, either by appropriately adjusting the injection current applied to the gain medium (in the case of an electrically pumped laser), or by appropriately adjusting the intensity of the pump laser applied to the gain medium (in the case of an optically pumped laser).

Brief Description Of The Drawings

These and other objects and features of the present invention will be more fully disclosed or rendered obvious by the following detailed description of the preferred embodiments of the invention, which is to be considered together with the accompanying drawings wherein like numbers refer to like parts and further wherein:

Fig. 1 is a schematic side view of a tunable Fabry-Perot filter;

Fig. 2 is a schematic side view of a tunable VCSEL;

Fig. 3 is a schematic diagram illustrating how the aforementioned vibrational problems may cause a relatively periodic modulation of the lasing frequency of a laser;

Fig. 4 is a schematic diagram illustrating how the aforementioned vibrational problems may cause a relatively irregular modulation of the lasing frequency of a laser;

Fig. 5 is a schematic diagram of a system for stabilizing the wavelength of an electrically pumped tunable laser; and

Fig. 6 is a schematic diagram of a system for stabilizing the wavelength of an optically pumped tunable laser.

Detailed Description Of The Preferred Embodiments

The present invention provides a fast and easy way to compensate for the aforementioned vibrational problems in tunable lasers, by correspondingly

adjusting the electrooptical performance of the laser's gain medium, whereby to eliminate the frequency shift due to vibrational factors.

More particularly, in a tunable laser of the sort disclosed in the aforementioned U.S. Patent Applications Serial Nos. 09/105,399, and 09/543,318, the output frequency of the laser may be affected by three variables, among others: (1) the tuning voltage applied to the laser, in the case of both electrically pumped and optically pumped lasers; (2) the injection current applied to the laser's gain medium, in the case of an electrically pumped laser; and (3) the intensity of the pump laser applied to the laser's gain medium, in the case of an optically pumped laser.

In particular, in the case of an electrically pumped laser, changing the injection current applied to the laser's gain medium causes a change in both the intensity of the laser's output and the output frequency of the laser. This is due to a corresponding change in the electrooptical performance of the laser's gain medium.

And in the case of an optically pumped laser, changing the intensity of the pump laser applied to the laser's gain medium causes a change in both the intensity of the laser's output and the output frequency of the laser. Again, this is due to a corresponding change in the electrooptical performance of the laser's gain medium.

The present invention is adapted to utilize one or the other of these phenomena, depending on whether the laser is electrically pumped or optically pumped, to selectively adjust the electrooptical performance of the laser's gain medium, whereby to eliminate the frequency shift due to the aforementioned vibrational factors.

More specifically, the present invention is adapted to (1) detect the frequency shift due to vibrational factors, and (2) compensate for this frequency shift by selectively modifying the electrooptical performance of the laser's gain medium, whereby to lock the laser to its target frequency. In the case of an electrically pumped laser, this

compensation is achieved by appropriately adjusting the injection current applied to the laser's gain medium; in the case of an optically pumped laser, this compensation is achieved by selectively adjusting the intensity of the pump laser applied to the laser's gain medium.

The system is implemented with a feedback mechanism. More particularly, a wavelength measuring module detects the difference between the instantaneous wavelength of the tunable laser and the desired wavelength of the laser, and generates a voltage signal which is representative of this difference. This voltage signal is then used to appropriately modify the electrooptical performance of the laser's gain medium, either by appropriately adjusting the injection current applied to the gain medium (in the case of an electrically pumped laser), or by appropriately adjusting the intensity of the pump laser applied to the gain medium (in the case of an optically pumped laser).

The particular wavelength measuring module used for the feedback mechanism can be any one of the many such devices well known in the art.

Looking now at Fig. 5, there is shown a preferred system for stabilizing the wavelength of an electrically pumped tunable laser 5. More particularly, the output of laser 5 is passed to a beamsplitter 10, where a portion of the laser's output is directed to a wavelength measuring module 15. Wavelength measuring module 15 is adapted to generate an output signal which is a function of the difference between the instantaneous wavelength of the tunable laser and the target wavelength of the laser. Preferably this output signal is in the form of a voltage signal whose magnitude varies according to the difference between the instantaneous wavelength of the tunable laser and the target wavelength of the laser. The output signal from wavelength measuring module 15 is then fed to a control unit 20, which modulates the pump current applied to tunable laser 5 according to the output signal of wavelength measuring module 15,

whereby to keep tunable laser 5 locked to its target frequency.

Correspondingly, and looking now at Fig. 6, there is shown a preferred system for stabilizing the wavelength of an optically pumped laser 5A. More particularly, the output of laser 5A is passed to a beamsplitter 10, where a portion of the laser's output is directed to a wavelength measuring module 15. Wavelength measuring module 15 is adapted to generate an output signal which is a function of the difference between the instantaneous wavelength of the tunable laser and the target wavelength of the laser. Preferably this output signal is in the form of a voltage signal whose magnitude varies according to the difference between the instantaneous wavelength of the tunable laser and the target wavelength of the laser. The output signal from wavelength measuring module 15 is then fed to a control unit 20, which modulates the pump current of a pump laser 25 according to the output signal of wavelength measuring module 15,

whereby to keep the tunable laser locked to its target frequency.

It is to be understood that the present invention is by no means limited to the particular constructions and method steps disclosed above and/or shown in the drawings, but also comprises any modifications or equivalents within the scope of the claims.